Technology of Metal Forming Processes
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Preface

Material Forming Technology is an interdisciplinary subject, encompassing the study of such topics as the behaviour and properties of metals, applied mechanics, metallurgy, heat transfer etc., and including the more practical and industrial aspects of the subject. In the past, the approach to the teaching of this subject was in general largely descriptive in nature, whereby only qualitative discussions of the processes and equipment were imparted to the students.

The current postgraduate and undergraduate syllabi for students of mechanical engineering, production engineering, and metallurgical engineering accommodate this subject matter in such order as to give them a better understanding of the engineering problems by presenting rational solutions which help in assimilating scientific principles.

This book is an attempt to present the subject of material forming technology by maintaining a proper balance between the theory and its applications. It is designed to serve as a textbook for the above engineering disciplines both at undergraduate and postgraduate levels. Besides, the book would be useful to practising engineers and researchers in the field of metal forming.

The first seven chapters are devoted to basic concepts and provide the students with a sound background in plasticity, in addition to highlighting the importance of friction and lubrication in metal forming processes. Only that portion of theory of plasticity is covered, which is relevant to the subsequent treatment of the subject matter of metalworking, because the book is not meant for the study of the theory of plasticity.

The remaining chapters cover specific forming processes and new and powerful techniques (load bounding and slip line field) for solving engineering problems in metal forming. The important factors in the study of individual processes such as force, power requirements, formability and machinability are briefly discussed. The analytical methods for the treatment of metal forming processes include the free-body equilibrium approach and energy methods. Friction characteristics at the interface are according to the constant shear factor, Coulomb’s friction law and the composite friction. The analysis is restricted only to plastic materials. In the final chapter, the application of computer-aided analysis to the metalworking processes has been demonstrated, which is the demand in this competitive scenario.
Because of the extensive information available in the field and desirability of exposing the student to other sources of knowledge, the references provided at the end of the book are somewhat more comprehensive than ordinarily found in a book of this nature.

I am indebted to many individuals for the help rendered on many fronts. This book has been an outcome of my extensive experience in teaching and guiding research in the field of technology. I wish to express my gratitude to all the distinguished authorities in the field whose works have inspired me in the preparation of my subject matter.

Finally, I would like to thank my family members for their patience, encouragement and cooperation during preparation of this manuscript.

Although great care has been taken to eliminate errors and misprints, it is inevitable that some will still be found. The author will appreciate being informed about these, and also welcome any comments and suggestions that the readers may wish to offer.

Surender Kumar
Nomenclature

Unless otherwise specified the following symbols have been used in the book:

- **$A$**: area
- **$A_0$**: dimensionless area ($A_0 = A_r/A$)
- **$A_r$**: real area of contact ($A_r = AA_0$)
- **$a_i$**: acceleration field
- **$B$**: coefficient, $B = b/h$; $B = \mu/\tan \alpha$
- **$2b$**: breadth or diameter of forging, width of rolled strip
- **$D$**: diameter
- **$d$**: depth
- **$E$**: modulus of elasticity
- **$e$**: strain, engineering strain
- **$\dot{e}_0$**: strain rate components
- **$f$**: feed rate
- **$G$**: torsion modulus, modulus of rigidity
- **$g$**: acceleration due to gravity
- **$h$**: thickness
- **$h_0$**: initial blank thickness
- **$I_1, I_2, I_3$**: stress invariants
- **$J'$**: upper bound energy consumption
- **$J_1, J_2, J_3$**: invariants (stress deviator, strain rate)
- **$K$**: yield stress in pure shear
- **$l$**: length
- **$m$**: constant, friction factor ($0 < m < 1$)
- **$n$**: normal unit vector, neutral point in rolling, strain hardening exponent, number of sides of polygonal disc
Nomenclature

\( O \) origin of co-ordinate system
\( P \) roll force, die load
\( p \) pressure
\( \bar{p} \) dimensionless die load, relative average pressure
\( R \) reduction
\( R_0 \) roll radius
\( r \) inner radius of bend, radius, radial distance
\( r, \theta, z \) cylindrical co-ordinate
\( r, \theta, \phi \) spherical co-ordinate
\( S \) surface of velocity discontinuity
\( S_{ij} \) components of stress deviator
\( S_i \) surface on which the stress vector \( T_i \) is prescribed
\( T \) torque
\( t \) time
\( U_i \) velocity
\( u_i \) displacement
\( V \) volume, velocity
\( v \) velocity
\( W \) work, work done per unit volume
\( \dot{W} \) power
\( x, y, z \) axes of a co-ordinate system

Greek Symbols

\( \alpha \) angle, die angle, bend angle, Mandrel angle
\( \alpha_i \) directional cosines
\( \alpha_2 \) angle of contact in rolling (plastic zone)
\( \beta \) barreling parameter
\( \gamma \) shearing strain
\( \eta \) coefficient of viscosity, efficiency
\( \Delta v \) velocity discontinuity, velocity difference
\( \varepsilon \) true strain
\( \varepsilon_0 \) effective strain
\( \dot{\varepsilon} \) true strain
\( \theta \) angular position
\( \mu \) coefficient of friction
\( \nu \) Poisson’s ratio
\( \mu, \nu \) Lode’s parameters
\( \rho \) density